

## Claims

1. A noise shaping arrangement for a phase locked loop,  
the arrangement comprising:
  - 5 a first order sigma-delta modulator (500) arranged to  
provide a first-order quantized output and a feedback  
path output (508);  
a second order sigma-delta modulator (520) coupled to  
receive the feedback path output (508) from the first  
10 order sigma-delta modulator (500) and arranged to provide  
a second order quantized output; and  
combination means (530) arranged to combine the first and  
second order quantized outputs to provide a combined  
third order quantized output (540),  
15 wherein the combined third order output provides noise  
shaping with a frequency notch spectrum.
2. The arrangement of claim 1 wherein the second order  
sigma-delta modulator is arranged with one or more  
20 complex conjugate pairs of zeros (270, 275).
3. The arrangement of claim 2 wherein the one or more  
complex conjugate pairs of zeroes (270, 275) is located  
on the unity circle.  
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4. The arrangement of claim 2 or 3 wherein the one or  
more complex conjugate pairs of zeroes (270, 275) is  
located away from the real axis.
- 30 5. The arrangement of claim 4 wherein the frequency  
location of the one or more complex pair of zeros is a

selected one of substantially 365kHz and substantially 518kHz.

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~~5.~~ The arrangement of any preceding claim where the  
5 feedback path output of the first order sigma-delta  
modulator received by the second order sigma-delta  
modulator is scaled (521) by a factor of substantially  
one quarter and wherein accumulators of the first order  
(504) and second order (522) sigma-delta modulator  
10 respectively have the same bit-size.

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~~6.~~ The arrangement of any preceding claim, further  
comprising a delay block (506) coupled between the  
feedback output of the first order sigma-delta modulator  
15 and the combination means.

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~~7.~~ The arrangement of any preceding claim wherein the  
combination means (530) includes scaling means (532, 534)  
coupled to scale the second order quantized output of the  
20 second order sigma-delta modulator by a predetermined  
scaling factor.

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~~8.~~ The arrangement of claim 7 wherein the predetermined  
scaling factor is substantially  $2^{-22}$ .

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~~9.~~ The arrangement of any preceding claim wherein the  
second order sigma-delta modulator (520) is operable to  
cancel the quantisation noise of the first order sigma-  
delta modulator (500).

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~~10~~<sup>11</sup>. The arrangement of any preceding claim wherein the feedback path output comprises a quantisation noise of the first order sigma-delta modulator (500).

5 ~~11~~<sup>12</sup>. The arrangement of any preceding claim wherein the frequency notch spectrum comprises at least one non-DC frequency notch.

~~12~~<sup>13</sup>. The arrangement of any preceding claim wherein the second order sigma-delta modulator (520) comprises a loop arrangement having a forward processing block (420) implementing the transfer function given by the z-transform:

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$$\frac{z^{-1}}{1 - 2z^{-1} \cos \theta + z^{-2}}$$

and a feedback processing block (450) implementing the function given by the z-transform:

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$$2 \cos \theta - z^{-1}$$

where

$$\theta = 2\pi \frac{f}{f_s}$$

25 and  $f$  is the desired notch frequency and  $f_s$  is the sample frequency.

~~13~~<sup>14</sup>. A phase locked loop incorporating the noise shaping arrangement of any preceding claim.

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14. A method for noise shaping in a phase-locked loop,  
the method comprising the steps of:

providing a first order quantized output from a first  
order sigma-delta modulator (500);

5 providing a second order quantized output from a second  
order sigma-delta modulator (520) coupled to receive a  
feedback path output (508) from the first sigma-delta  
modulator (500);

combining (530) the first and the second order quantized  
10 outputs to provide a combined third order quantized  
output (540),

wherein the combined third order output provides noise  
shaping with a frequency notch spectrum.

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15 15. The arrangement, phase locked loop or method of any  
preceding claim wherein the phase locked loop is a  
fractional-n phase locked loop frequency synthesizer.